DOCTOR
OF
PHILOSOPHY

SWELL ACROSS THE CONTINENTAL SHELF

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The transformation of surface gravity waves propagating through shallow regions is investigated with extensive field data from the North Carolina continental shelf. A spectral energy balance equation is derived for a bi-dimensional bottom topography with random small-scale irregularities, in which bottom friction is introduced heuristically which a parameterized source term, and solved numerically using a hybrid Eulerian-Lagrangian scheme. This new model named CREST (Coupled Rays with Eulerian Source Terms) determines accurately refraction of waves by subgrid-scale depths variations using precomputed rays, allowing applications to large coastal areas with relatively coarse grids. Hindcasts of swell events during field experiments show large variations in wave heights caused by refraction and bottom friction. Widespread observations of sand ripples confirm that the bottom roughness is enhanced by wave-generated vortex ripples, thus sheltering the shore from offshore swells by dissipating wave energy in the bottom boundary layer. Resulting wave height attenuation up to 70% (84% of the wave energy) was observed in moderately energetic conditions. Bragg scattering of waves by wavelength-scale bottom features significantly increases (up to a factor two) the directional spread of waves.

MULTI-BLOCK PARALLEL NAVIER-STOKES SIMULATION OF UNSTEADY WIND TUNNEL AND GROUND INTERFERENCE EFFECTS

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A numerical investigation of unsteady wind tunnel and ground interference effects is carried out in the time domain to study the transonic flutter characteristics of the NLR 7301 section inside a wind tunnel and the thrust generation characteristics of a NACA0014 airfoil plunging near a ground plane. A parallelized, multi-block, deforming grid, unsteady flow-solver is coupled with a two-degree-of-freedom structural model.

For the transonic flutter problem, two types of porous-wall boundary-conditions are implemented and tested for the boundaries representing the tunnel walls. The type of porous boundary condition is found to influence significantly both steady and unsteady solutions. Results show that the free-flight flutter behavior may differ significantly from the behavior found in a porous wind tunnel because of the strong dependence on the tunnel porosity parameter and the proximity of the walls.

An analysis of the trailing edge boundary condition is performed for the airfoil in ground effect. The computations show that this boundary condition influences the solution only when non-linearities are present in the flow-field, although parameters averaged through a cycle of oscillation are not affected significantly. The same behavior is observed for the influence of the turbulence model on the fully-

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turbulent, unsteady computations. However, the best agreement with low Reynolds number, experimental data is obtained when the flow is assumed laminar and no turbulence model is applied.

PERFORMANCE OF SERIALLY CONCATENATED CONVOLUTIONAL CODES WITH BINARY MODULATION IN AWGN AND NOISE JAMMING OVER RAYLEIGH FADING CHANNELS

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In this dissertation, the bit error rates for serially concatenated convolutional codes (SCCC) for both BPSK and DPSK modulation with different channel conditions and with (and without) spread spectrum are considered. For low signal-to-noise ratios, simulation results are used, while for higher signal-to-noise ratios, an average upper bound is developed to illustrate the achievable performance of SCCC. The theoretical bounds for SCCC BPSK and SCCC DPSK with AWGN, noise jamming, Rayleigh fading, and spread spectrum are developed, analyzed, and compared with simulation results. The differences in performance between SCCC BPSK and SCCC DPSK are described. Implications for the military communications user and jammer are also discussed.

EXPERIMENTAL INVESTIGATION OF LOW SPEED FLOW OVER FLAPPING AIRFOILS AND AIRFOIL COMBINATIONS

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A wind tunnel investigation of low speed flow over flapping airfoils and airfoil combinations was performed using flow visualization and laser Doppler velocimetry. Specifically, three cases were studied: A NACA0014 airfoil oscillating in a sinusoidal plunge mode, A NACA0014 airfoil oscillating in a sinusoidal plunge mode near a ground plane, and two NACA0014 airfoils arranged in a biplane configuration and oscillating in counterphase in a sinusoidal plunge mode. The plunge amplitude-to-airfoil chord ratio was 0.4, the reduced frequency of oscillation was 1.0 and the Reynolds number based on airfoil chord was set at 8760.

Conditionally sampled measurements of the axial flow velocity were taken at numerous flow held points providing detailed information about the flow features generated by this type of flapping motion. These measurements were complemented by time-averaged flowfield data and by visualization of the instantaneous flow held at various points during the flapping cycle. Furthermore, the thrust generated by the sinusoidal plunge motion was measured with a laser range. The results show that vortex shedding occurs both from the airfoil leading and trailing edge.

SIMULATED ANNUAL AND SEASONAL ARCTIC OCEAN AND SEA-ICE VARIABILITY FROM A HIGH RESOLUTION, COUPLED ICE-OCEAN MODEL

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The role of the Arctic Ocean in global thermohaline circulation and climate change is not well understood. High resolution, physically realistic simulations of the Arctic Ocean, calibrated and validated with observations and paleo-climate data, may provide the spatial and temporal coverage and resolution to more accurately characterize Arctic Ocean circulation, large-scale inter-ocean exchanges and allow future conditions to be projected correctly.

A 1/12-degree (~9 km) resolution coupled ice-ocean model, optimized for massively parallel computers, was developed. The model employs the latest digital bathymetry and ocean climatology available. Decades of model integration using climatological and realistic daily varying atmospheric forcing were performed.

Comparisons of model output with climatic atlases and observations indicate greatly improved representation of circulation, ocean and sea-ice characteristics, mass and property transports and water mass transformations. Areas where model physics and resolution improvements are needed are highlighted as well.

Comparison with a 1/6 degree (~18 km) ice-ocean model quantifies improvements gained from doubling model resolution. A ten-fold increase in eddy kinetic energy is seen in the 9 km model versus the 18 km model. Narrow shelf and slope boundary currents, absent in the latter, now appear and mass and property transports are closer to observed values.

NEARSHORE WAVE AND CURRENT DYNAMICS

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Mean cross-shore wave height transformation and alongshore currents observed on near-planar and barred beaches are compared with predictions based on the nearshore numerical model Delft3D. Delft3D solves the two-dimensional, depth-averaged, momentum balance (2-DH) between forcing (by breaking waves and variations in mean surface elevation), changes in momentum flux, bottom stress and lateral mixing. The observations were acquired on the near-planar California beaches at Torrey Pines and Santa Barbara and the barred beach at Duck, N.C., and include a wide range of conditions with maximum mean currents of 1.5 m/s. The model has two free parameters, a depth dependent breaking term, γ , and the bed roughness length, $s\ k$. An empirical formula to determine γ *a priori* from the deep-water wave steepness and bed slope is developed, showing good agreement in the wave height transformation. Including rollers in the wave forcing results in improved predictions of the observed alongshore current structure by shifting the predicted velocity maxima shoreward and increasing the velocity in the trough of the bar compared with model predictions without rollers. On near-planar beaches and high-energy events on barred beaches, a one-dimensional (alongshore uniform bathymetry) model performs as well as 2-DH. On barred beaches under moderate conditions when alongshore non-uniform bathymetry prevails, the 2-DH model performs

better than the 1-D model, particularly in the bar-trough region. Wave forcing balances the bottom stress with a second balance between alongshore variation in the mean surface elevation (pressure gradients) and the inertia of the alongshore current.

OPTIMIZATION OF DISTRIBUTED, OBJECT-ORIENTED ARCHITECTURES

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Object-Oriented computing is fast becoming the de-facto standard for software development. Optimal deployment strategies for object servers change given variations in object servers, client applications, operational missions, hardware modifications, and various other changes to the environment. Once distributed object servers become more prevalent, there will be a need to optimize the deployment of object servers to best serve the end user's changing needs. Having a system that automatically generates object server deployment strategies would allow users to take full advantage of their network of computers. Many systems have very predictable points in time where the usage of a network changes. These systems are usually characterized by shift changes where the manning and functions preformed change from shift to shift. We propose a pro-active optimization approach that uses predictable indicators like season, mission, and other foreseeable periodic events. The proposed method profiles object servers, client applications, user inputs and network resources. These profiles determine a system of equations that is solved to produce an optimal deployment strategy for the predicted upcoming usage by the users of the system of computers and servers.

A COMPUTATIONALLY EFFICIENT ALGORITHM FOR DISTURBANCE CANCELLATION TO MEET THE REQUIREMENTS FOR OPTICAL PAYLOADS IN SATELLITES

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Vibration control is a very important issue in satellites. The new high-resolution digital imaging devices are especially sensitive to vibrations. Antennas used in laser communications also require a very quiet environment so that their performance is not degraded. The Stewart platform is capable of isolating an optical payload from the noisy spacecraft bus. Until recently, only passive methods were used in all vibration isolation applications. Recent advances in Digital Signal Processing techniques made the development of vibration control algorithms possible, but these usually require large computational power. This work explores using a computationally efficient vibration-isolation method for optical payloads by using hexapods. The method suppresses the vibration at the assigned frequencies and does not affect unassigned frequencies if the plant is linear.

The mathematical analysis includes convergence analysis and the effect of unassigned frequencies in the output. The computational requirements of the algorithm is evaluated and is compared to the Multiple-Error Least Mean Square. The method is very robust to nonlinearities; its performance is comparable to the Multiple-Error Least Mean Square with a fraction of the computational time and memory requirements. It also requires very little plant knowledge. Theoretical results are verified through simulations using a Single-Input/Single-Output plant and a nonlinear hexapod model. The controller was also experimentally validated in two different hexapods and the performance was found to be similar to or better than the performance obtained with the Multiple-Error Least Mean Square method when a noisy reference signal is used.

APPLICATIONS OF LARGE AMPLITUDE BROADBAND ACOUSTIC NOISE TO ACOUSTOPHORESIS

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Theoretical results show that the drag on a resonant object can be modified by the presence of homogeneous, broadband acoustic noise, when the band overlaps the object's resonance width. While the results constitute an acoustic analog to the Einstein-Hopf drag on an oscillating dipole in the presence of electromagnetic fluctuations, an important difference is that band limited acoustic noise can reduce the drag when the lower frequency of the spectrum coincides with the resonant frequency of the resonator. Experimental evidence of the increased drag on a bubble is shown. Both increased and reduced drag on aerogel spheres configured as the bob of a parametrically driven pendulum are reported. Applications to separation processes, in particular a design that can be used for extraction of water in both fuel and lubrication oil systems and extraction of oil in bilge water, are suggested.